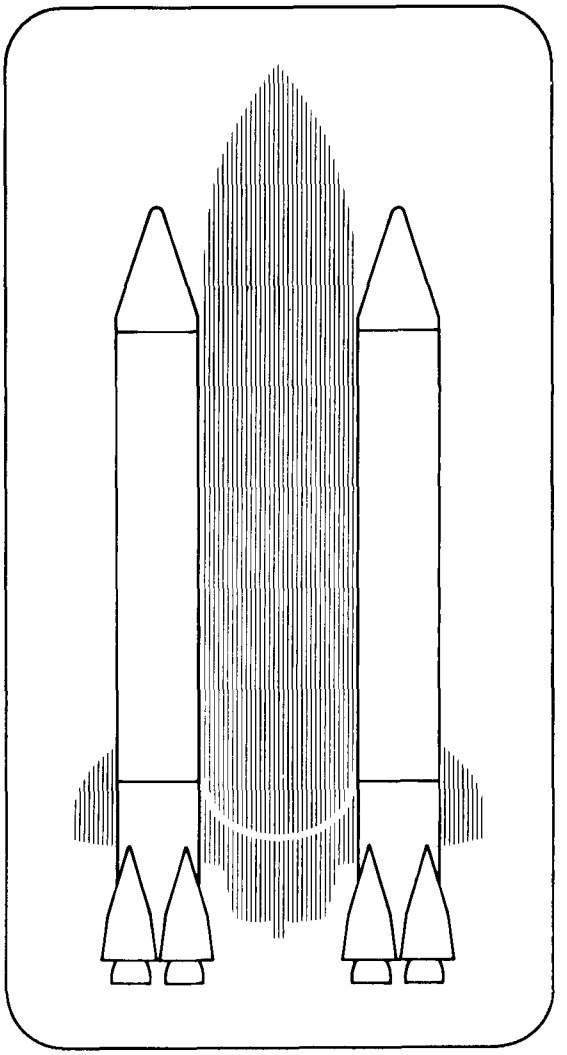
NAS8-37136
DR-1

October 1987

Study Plan

Liquid Rocket Booster (LRB) for the Space Transportation System (STS) Systems Study



MARTIN MARIETTA

MICHOUD AEROSPACE

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Study Plan

Liquid Rocket Booster (LRB) for the Space Transportation System (STS) Systems Study

Approved by:

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Study Manager

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FIGURES

Introduction

Martin Marietta's study plan is submitted in accordance with DPD-696 (DR-1). The two major objectives of the plan are: to present our study approach, and to provide the standard for guiding the Liquid Rocket Booster (LRB) project.

The plan presents our full compliance with the Request for Proposal (RFP) and its scope includes: (1) concise task plans; (2) a study flow diagram (depicting task interrelationships); (3) a study schedule of control points; (4) time-phased manloading and skills by task; (5) major subcontractors (with their areas of responsibility/management relationships identified); and (6) a list of required government-provided documentation.

When approved by the Marshall Space Flight Center (MSFC), the study plan will serve as the primary study control document for the MSFC Technical Manager and the Martin Marietta Study Manager. There are no technical considerations or constraints that preclude Martin Marietta from successfully executing this study.

1. Task Plans

The task plans (Figure 1-1) provide a comprehensive description of the work to be performed. Each plan is presented on a fold-out sheet that shows the task description, approach, timeframe, inputs/outputs, manloading, and management lead responsibility. The task plans form a basic element of the study management and control.

2. Study Flow Diagram

A logic network depicting tasks/subtasks, interrelationships, and time-phasing, is described in Figure 2-1.

3. Study Milestone Schedule

Figure 3-1 defines the milestones and timelines for all tasks and subtasks.

4. Time-Phased Man-Loading

The tasks and labor classifications/skills required for this study effort are listed in Figures 4-1 and -2.

5. Major Subcontractors

The subcontractors who will assist us on this project are: Aerojet Tech Systems, Co.; Honeywell, Inc., Space and Strategic Avionics Division; and Pioneer Systems, Inc., Aerospace Recovery Division. Their selection was based on their past and current experience and performance on similar programs. Each subcontractor is uniquely qualified in the areas they will support. All three subcontractors will report directly to the study manager, Mr. Thomas Mobley. Figure 5-1 provides the scope, task descriptions, and schedules for each subcontractor.

6. Documentation Required

Data are required from the following studies as described in the RFP: (1) Space Transportation Booster Engines (STBE); (2) Space Transportation Main Engines (STME); (3) in-depth analyses of the integration of candidate LRB concepts into the Space Transportation System (STS) flight system; and (4) the adaptation of LRBs into STS launch facilities and operations.

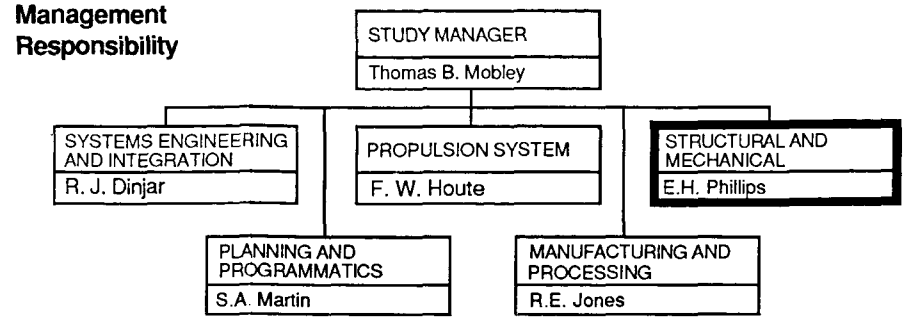
Task Description:
TASK 1.0 (TASK A) LIQUID ROCKET BOOSTER TRADE ANALYSES

Michoud Aerospace will perform trades and analyses to identify and define the LRB concepts and supporting operations and facilities that best satisfy the requirements for STS boosters. Basic characteristics of the concept/systems will be identified and included in data sheets.

Task Objective:
TASK 1.0 (TASK A) LIQUID ROCKET BOOSTER TRADE ANALYSES

Develop recommended booster concepts that will be further defined in Task E, System Definition.

Management Responsibility



Task Approach

TASK 1.0 (TASK A) LIQUID ROCKET BOOSTER TRADE ANALYSES

1.1 Vehicle Requirements - Based on Martin Marietta's experience on ET/STS and our extensive database, develop LRB/STS Level II requirements, including: 1) mission operations; 2) integration; 3) mission analyses; 4) LRB/STS environments; 5) software. For Level III, develop the requirements for: 1) structural; 2) purge/vent and hazardous gas detection system; 3) environmental protection; 4) LRB separation; 5) LRB safing; 6) LRB deceleration; 7) requirements documentation; and 8) test.

1.2 Preliminary Baseline Concepts Development - Data from previous contractual and IR&D studies will be augmented with preliminary trades and analyses to develop preliminary concepts baselines for both pump-fed and pressure-fed booster systems.

1.3 Preliminary System Analyses - Systems anlayses of the preliminary concepts developed in Task 1.2 will provide preliminary flight mechanics, and mass properties data in support of other study tasks.

1.4 Detail Trade Studies and Analyses - Detail trade studies and supporting analyses will be performed to optimize both the pump-fed and pressure-fed systems developed in Task 1.2 on a performance (pound to orbit) and cost (development, production, operations) basis. Areas to be investigated include: 1) alternate propellants; 2) propulsion system types; 3) tank pressure (pressure-fed); 4) engine chamber pressure; 5) performance/weights; 6) tank construction materials; 7) tank construction (design/sizing); 8) avionics/electrical (including "next generation" concepts-bite/autonomy); 9) recovery/expendable boosters (all or part); 10) recovery concepts; 11) flight systems (control); 12) performance/trajectory shaping. Analyses in support of the trades include structures, propulsion, thermal/aero, flight mechanics, materials, mass properties, avionics, and electrical.

1.5 Vehicle Trade and Analyses - The preferred pump-fed and pressure-fed vehicle will be selected based on the evaluation criteria developed in Task 1.6. The finalist configurations will be compared based on performance, STS impact, and cost, from which a preferred configuration will be recommended for NASA approval for further definition in contract Task E.

1.6 Configuration Evaluation Criteria Plan (DR-10) - A plan will be developed for NASA approval which will provide the rationale and criteria for configuration evaluation and the selection of the recommended configuration.

Task Inputs

- A - Prior MSFC LRB Study
- B - Pressure-Fed Propulsion Systems (Task B)
- C - Evolution/ Growth Potential (Task C)
- D - Preliminary Analyses of STS Integration (Task D)
- E - Supporting Studies Coordination (Task F)
- F - Project Planning (Task G)
- G - Shuttle Operations Data Book (JSC-08934)
- H - Space Shuttle Flight & Ground Systems Specification (JSC-07700, Vol X)
- I - RFP Guidelines & Assumptions

Task Outputs

1 - Preliminary Baseline Concepts
2 - Preliminary Analyses of STS Integration (Task D)
3 - System Definition (Task E)
4 - Configuration Evaluation Criteria Plan (DR-10)
5 - Recommended Baseline LRB Concepts/ Rationale/ Selection
6 - Project Planning (Task G)
7 - Performance Review Documentation
8 - Final Report
9 - Technical Issue Listing
10 - Evolution/Growth Potential (Task C)
11 - Pressure-Fed Propulsion Systems (Task B)
12 - Supporting Studies & Coordination (Task F)

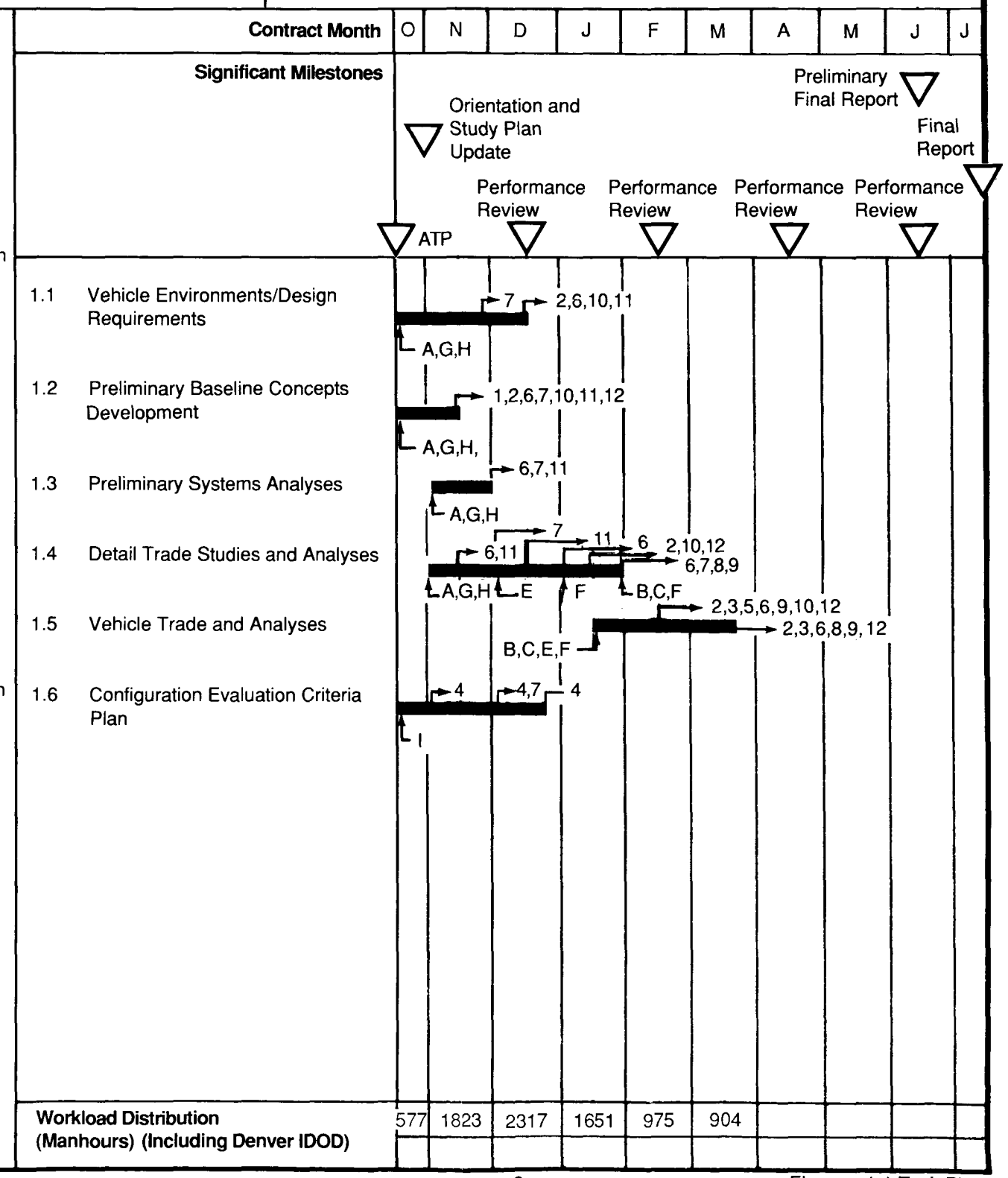


Figure 1-1 Task Plans

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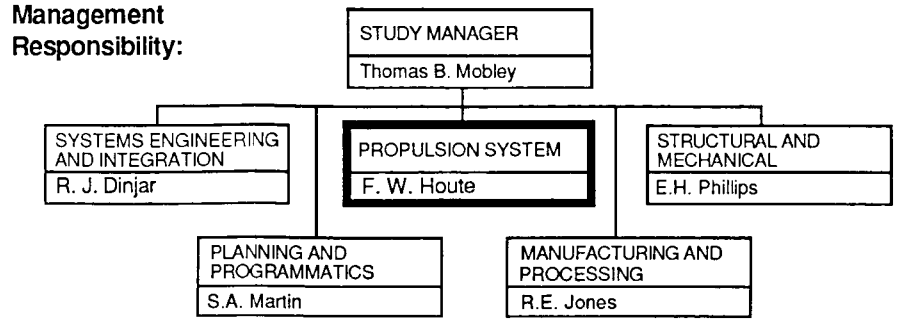
Task Description:
TASK 2.0 (TASK B) PRESSURE-FED PROPULSION SYSTEM

Through subcontract(s) obtain data on pressure-fed engine/systems which shall include parametric data vehicle sizing, engine concept/design data, and planning information.

Task Objective:
TASK 2.0 (TASK B) PRESSURE-FED PROPULSION SYSTEM

Develop sufficient data to enable the selection of the preferred pressure-fed propulsion system for comparison with pump-fed systems and for further definition.

Management Responsibility:



Task Approach

TASK 2.0 (TASK B) PRESSURE-FED PROPULSION SYSTEM

Effective execution of the subtasks below by the selected subcontractor(s) will provide data in sufficient depth to allow propulsion systems recommendations, with rationale for the baseline booster or concepts.

2.1 Pressure-Fed Propulsion System Trades and Analyses - Detail trade studies and analyses will be performed to determine an optimum pressure-fed propulsion system concept. Trades and analyses will include at the minimum: 1) chamber pressure; 2) tank pressure; 3) pressurization system; 4) engine configuration; 5) propellant options; 6) feed systems; 7) TVC systems; 8) engine thrust and ISP; 9) propellant ratios; 10) engine life and refurbishment; 11) cost and schedule.

2.2 Pressure-Fed Booster Configuration Trades and Analyses - The subcontractor will provide support for the conceptual design of the pressure-fed propulsion systems vehicle by assessing vehicle configuration options impacts on the propulsion systems.

2.3 Technology/Advanced Development Requirements - Based on the effort in Tasks 2.1 and 2.2 above identify technology or advanced development efforts that are required to advance the state-of-the-art or to properly demonstrate the capabilities of pressure-fed propulsion systems.

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Task Inputs

A - Project Planning (Task G)
B - Prior LRB Study Results
C - Trades and Analyses (Task A)
D - Supporting Studies & Coord (Task F)
E - Shuttle Ops Data Book (JSC-08934)
F - Space Shuttle Flt & Grnd Sys Spec (JSC-07700, Vol X)

Task Outputs

1 - Trades & Analyses (Task A)
2 - Program Planning (Task G)
3 - Recommended Pressure-Fed Vehicle
4 - Recommended Pressure-Fed Engine
5 - Performance Review Documentation
6 - Final Report
7 - Advance Development Requirements
8 - Systems Definition (Task E)
9 - Evolution/Growth Potential (Task C)

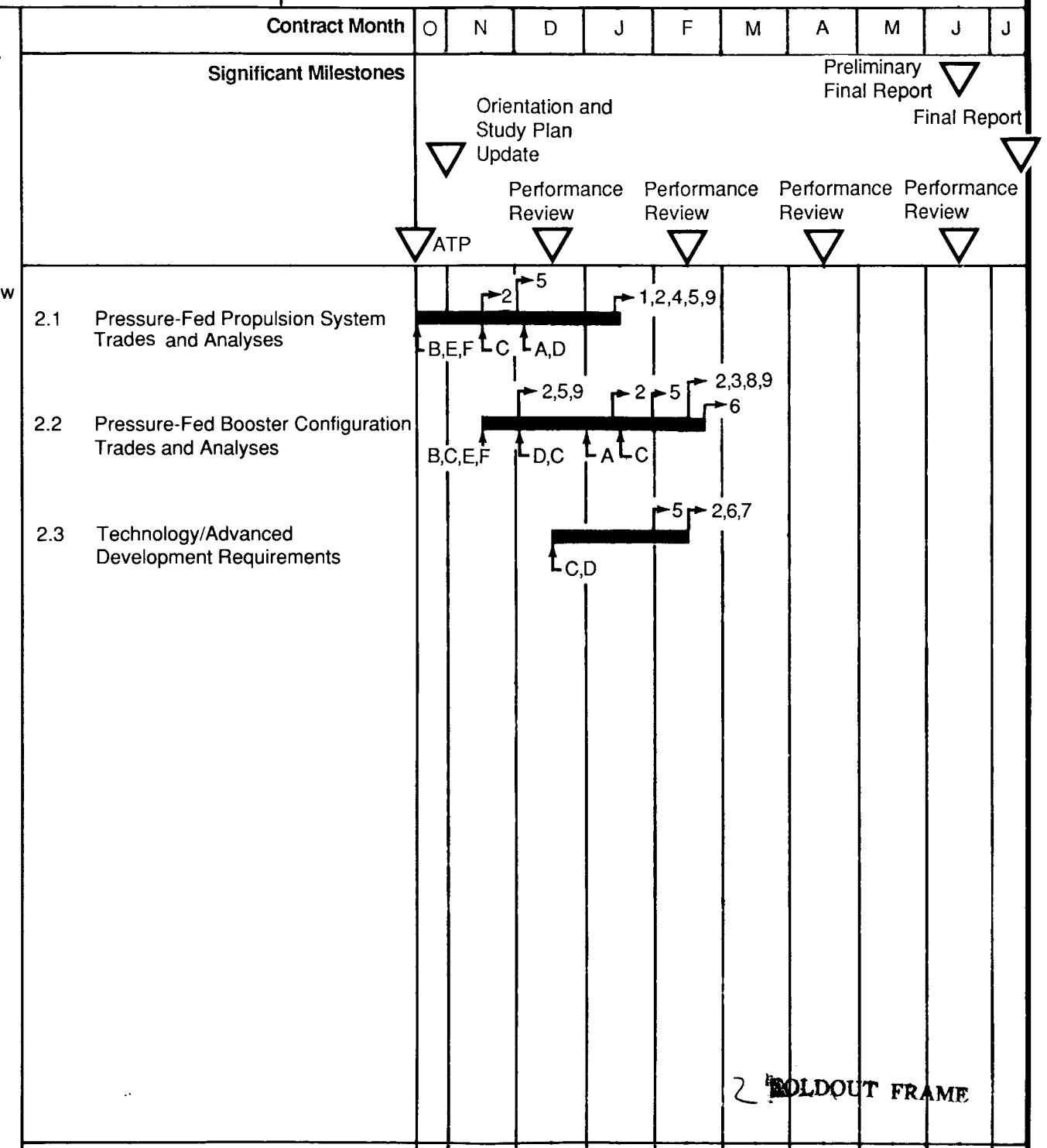

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Figure 1-1 (Continued)

Task Description:

TASK 3.0 (TASK C) EVOLUTION/GROWTH POTENTIAL

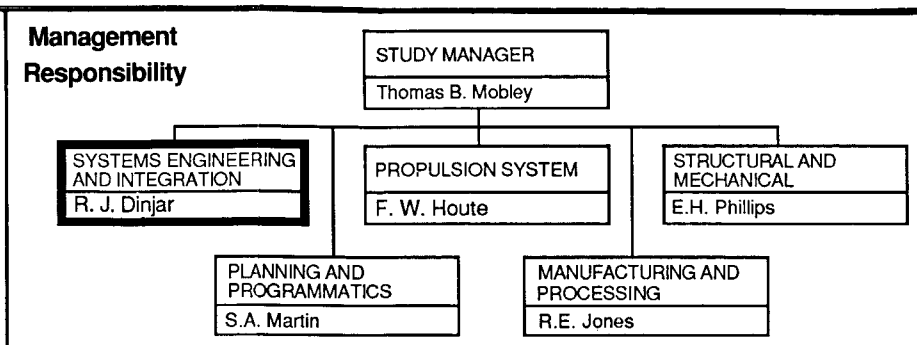
Examine STS/LRB concepts for possible growth or evolution in terms of increased capability and/or improved operations characteristics. Determine the application of the LRB concepts for other planned or potential future launch vehicles. In addition, examine avionics systems capable of meeting evolving/future vehicle concepts.

Task Objective:

TASK 3.0 (TASK C) EVOLUTION/GROWTH POTENTIAL

Identify initial STS/LRB concepts areas that have potential growth or evolution that will increase booster capability and/or improved operations characteristics. Identify potential application of the LRB concepts for other planned or potential launch vehicles. Identify avionics systems that are capable of meeting evolving/future launch vehicles requirements.

Management Responsibility



Task Approach

TASK 3.0 (TASK C) EVOLUTION/GROWTH POTENTIAL

3.1 Trajectory Performance Analyses - A range of potential propulsion and vehicle alternative configurations will be analyzed to determine which will satisfy stated and potential mission requirements. These data will establish the requirements for Tasks 3.2 and 3.3 below.

3.2 Engine Growth Concepts - Both pressure-fed and pump-fed propulsion systems will be analyzed with subcontractor support to determine the amount of potential growth, or if the systems evolve into an advanced system that would increase booster capability and/or improve operations characteristics.

3.3 Vehicle Concept Analyses - Vehicle configuration and sizing will be analyzed to determine the potential growth or evolution options available to increase booster capability and/or improve operations characteristics. In addition, the impacts generated by Tasks 3.1 and 3.2 above will be assessed.

3.4 Future Vehicle Application - The LRB system will be examined for potential utilization on other currently planned or potential future launch vehicles.

3.5 Future Vehicle Avionics Analyses - The avionics system selected will be analyzed to determine its capability to meet evolving/future vehicle concepts requirements and also identify avionics growth or evolution requirements that may be necessary to meet the future vehicle system requirements.

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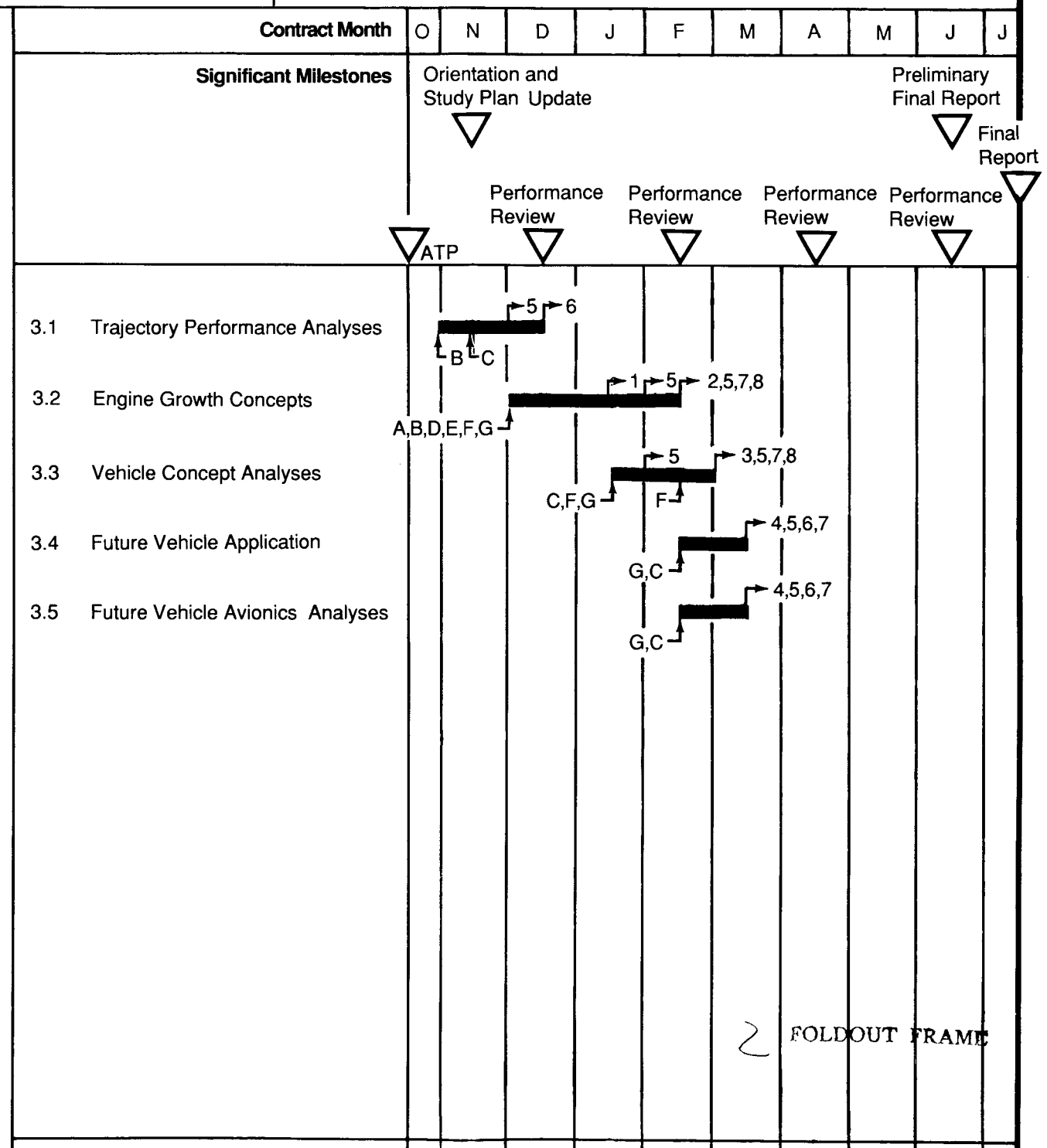
Task Inputs

A - STAS
B - Prior Adv Launch Vehicle Studies
C - Trades and Analyses (Task A)
D - Shuttle Ops Data Book (JSC-80934)
E - Space Shuttle Flt Grnd Sys Spec (JSC-07700, Vol X)
F - Pressure-Fed Propulsion Systems (Task B)
G - Supporting Studies & Coordination (Task F)

Task Outputs

1 - Trades & Analyses (Task A)
2 - ID of Growth Areas
3 - ID of Potential Application other Programs
4 - Advanced Development Requirements
5 - Performance Review Documentation
6 - Final Report
7 - Project Planning (Task G)
8 - Systems Definition (Task E)



Workload Distribution (Manhours)	249	355	272	616	518				

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Figure 1-1 (Continued)

Task Description:

TASK 4.0 (TASK D) PRELIMINARY ANALYSES OF STS INTEGRATION

Perform preliminary analyses of LRB/STS integration to determine and examine impacts to the current LRB/STS vehicle system, concentrating on areas identified in the RFP.

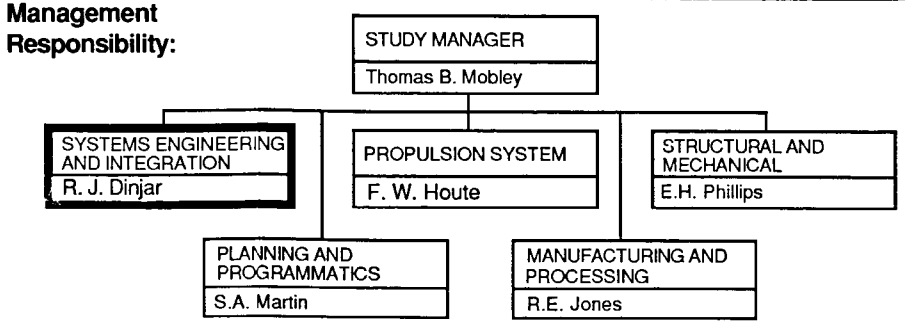
Task Objective:

TASK 4.0 (TASK D) PRELIMINARY ANALYSES OF STS INTEGRATION

On selected LRB concepts, the data listed below will be provided to allow for a more detailed examination of LRB/STS integration that is planned for a separate comparison effort.

- Booster physical configuration data
- Selected propellant and characteristics
- Preliminary booster structural math model (liftoff and boost)
- Preliminary MLP structural math model to reflect anticipated design changes
- Booster engine failure modes/probabilities
- Ground processing concepts

Management Responsibility:



Task Approach:

4.0 (TASK D) PRELIMINARY ANALYSIS OF STS INTEGRATION

4.1 Environment Definition-Develop preliminary lift-off, ascent, and reentry environments for the LRB. Aerodynamics analysis will provide aerodynamic force and moment coefficients, reentry drag coefficients, and LRB running loads. Induced aerothermal ascent and reentry environments will be computed. Plume environments including base heating and lift-off acoustics and pressure will be determined.

4.2 Loads/Dynamics Analyses-Define static load paths between Orbiter, ET, LRB, and MLP. Vehicle loads, dynamics, hold-down loads will be determined resulting from LRB/SSME engine start sequence and LRB engine shutdown sequence scenarios developed in Task 4.1. Loads and dynamics resulting from vehicle control requirement will also be determined. In addition, we will determine the implications of basic vehicle modal frequency and acoustics.

4.3 LRB/STS Dimensional Analyses-Develop/prioritize dimensional constraints, considering such constraints as interface clearances, facility and transportation limitations aerodynamic impacts.

4.4 Mission Analyses-Analyses-Determine LRB/SSME start sequence, LRB shutdown/separation sequences, to assess the impact on vehicle loads, dynamics, hold-down loads, and to determine resulting control requirements and aerodynamics impacts. In addition, ascent profiles analyses will be conducted to determine thrust vs time, total impulse and preliminary conducted to determine thrust vs time, total impulse and preliminary gimbal requirements to accomplish mission requirements at ETR/WTR.

Perform LRB separation impact analysis based on the Task 4.1 separation scenario and effects of cg, aerodynamics engine shutdown, and/or thrust changes: develop an optimum separation system. Conduct analyses of flight control requirements during LRB boost/shutdown for launches out of ETR/WTR. The analyses will investigate thrust vs time, total impulse requirements, gimbal requirements, control requirements to maintain vehicle trajectory within Orbiter/ET constraints, control requirements due to shift in cg over time and control requirements for aborts if nominal operations does not shut down engines.

Various LRB/SSME abort scenarios will be studied, considering impacts to the current abort mode and any additional capability with LRBs will be identified in conjunction with Task 4.5.

4.5 Propellant Loading Analyses-Based on configuration, develop propellant loading sequence and timelines.

4.6 Impacts Assessment-Based on the recommended LRB/STS configuration, qualitative assessments of impacts will be developed.

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Task Inputs

- A - Shuttle Operations Data Book (JSC-08934)
- B - Space Shuttle Flight Ground System Specification (JSC-07700, Vol X)
- C - Trades and Analyses (Task A)
- D - Prior LRB Study Results
- E - System Definition (Task E)
- F - Pressure-Fed Propulsion System (Task B)
- G - Project Planning (Task G)

Task Outputs

1 - LRB Configuration Data
2 - Selected Propellant and Characteristics
3 - Preliminary LRB Structure Math Model
4 - Preliminary MLP Structure Math Model
5 - Booster Engine Failure Modes/Prob
6 - Ground Processing Concepts
7 - Performance Review Documentation
8 - Project Planning (Task G)
9 - Systems Definition (Task E)
10 - Final Report

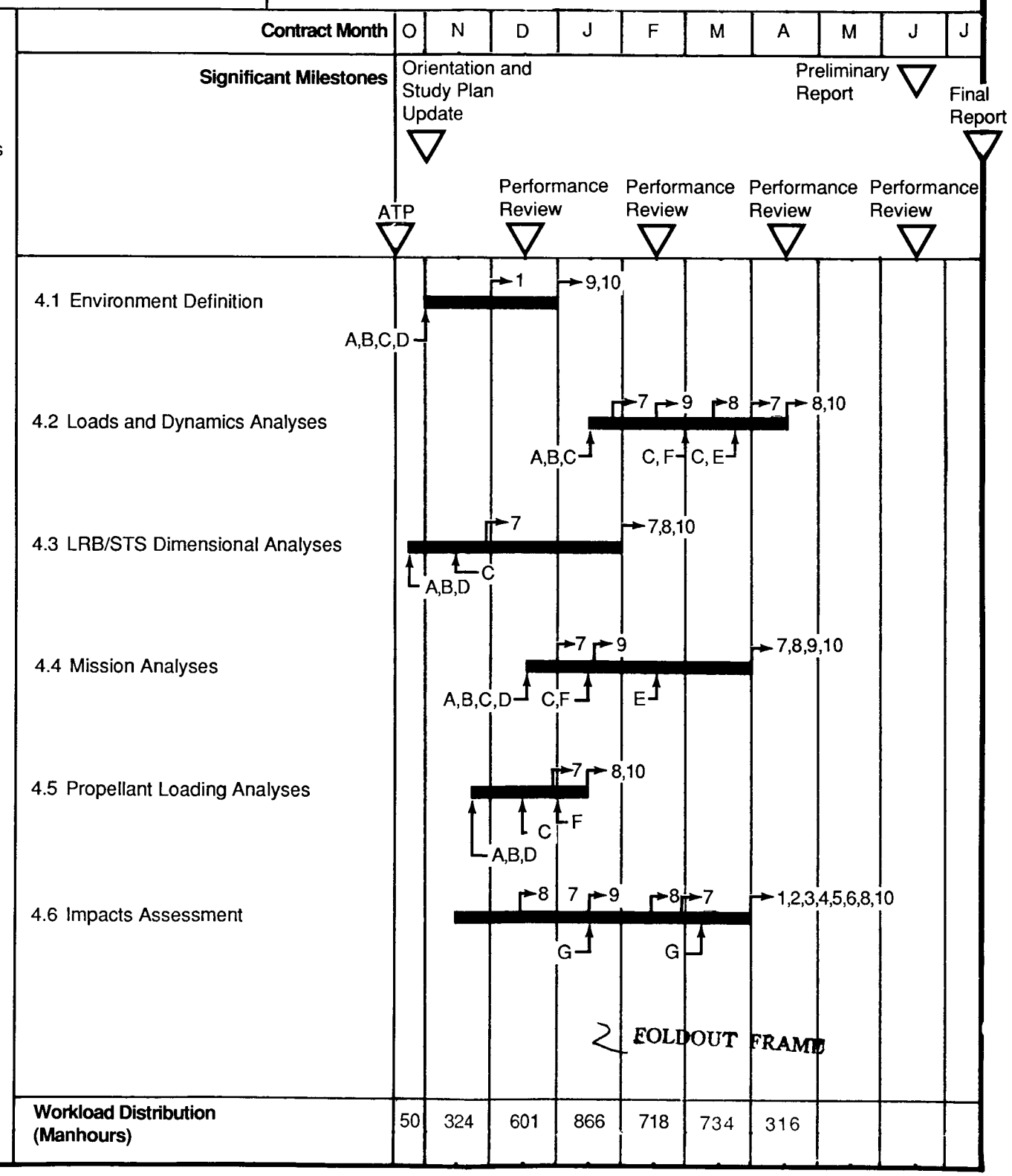


Figure 1-1 (Continued)

Task Description:

TASK 5.0 (TASK E) SYSTEM DEFINITION

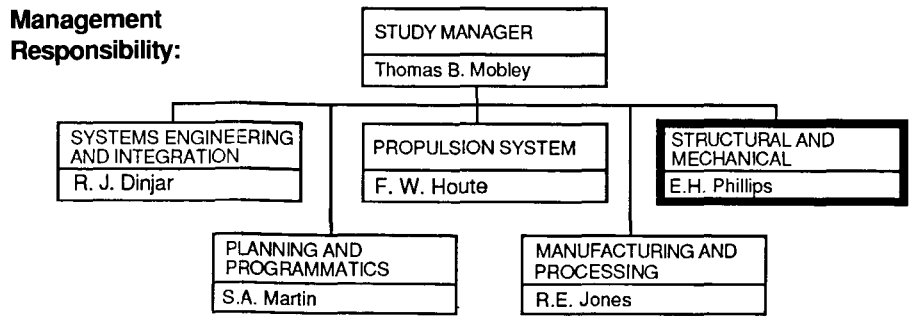
Develop basic drawing and definition/analysis of the NASA approved LRB configuration(s) resulting from the trade analyses in Task A. The system description is to be in sufficient detail and depth that performance, size, weights, components, subsystems integration, maintainability, operations, etc., can be defined. The description should include at a minimum, where appropriate, impacts of the total vehicle system, facilities, ground support equipment, operations, hazards, etc.

Task Objective:

TASK 5.0 (TASK E) SYSTEM DEFINITION

Develop a system definition of the NASA approved LRB/STS concept(s). Provide documentation, including engineering drawings, detail weight statements, analysis results displayed in graphs, tables, charts, floor diagrams, and system/subsystems descriptions.

Management Responsibility:



Task Approach

TASK 5.0 (TASK E) SYSTEM DEFINITION

5.1 LRB/STS Vehicle Configuration Definition - Analyses and design efforts will provide basic engineering drawings and subsystem definition, including structures, mechanical systems, environmental protection, propulsion and fluid systems, electrical/avionics (including redundancy), and interfaces/integration. As part of the overall definition, reliability, maintainability, and operations will be defined for the selected system.

5.2 Vehicle System Analyses - System analyses of the selected concept including loads, dynamics, stress, weights, mass properties, acoustic loads, and base thermal environments will be performed in support of this overall vehicle design/definition effort.

5.3 Vehicle Mission Analyses - Perform flight operations and flight mechanics analyses will be performed to refine flight operations requirements and system performance data for the selected concept. This definition/analysis will include ascent aerodynamics, booster separation and reentry aerodynamics. A six (6) degree-of-freedom ascent stability and control study will be conducted to assue the LRB/STS system stays within the current STS constraints. A dynamics six (6) degree-of-freedom reentry analysis will also be performed for the reusable LRB for further recovery system development. This task will also include a booster separation analysis to assure the separation envelope of the LRB/STS system.

5.4 Performance Anomalies Analyses - Definition of the engine-out capability will be developed including both orbiter and LRB to access performance impact to the LRB/STS system compared to SRB/STS system. Coupled with this task, abort options from initial engine ignition through MECO will be developed for the LRB/STS system and those options over the current STS system will be defined.

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Task Inputs

- A - Trade Analyses (Task A)
- B - Pressure-Fed Propulsion System (Task B)
- C - Shuttle Operations Data Book (JSC-08934)
- D - Space Shuttle Flight Ground System Specification (JSC-07700, Vol X)
- E - Supporting Studies Coordination (Task F)
- F - Preliminary Analyses of STS Integration (Task D)
- G - NASA Approved Baseline Configuration
- H - Project Planning (Task G)

Task Outputs

1. Basic Configuration Drawings
2. Performance Review Documentation
3. Project Planning Tasks (Task G)
4. Preliminary Analyses of STS Integration (Task D)
5. Operations Definition
6. Maintainability Definition
7. Weight Statements
8. Facility Impacts
9. Ground Support Equipment Impacts
10. Hazards ID
11. Final Study Report
12. Supporting Studies and Coordination (Task F)

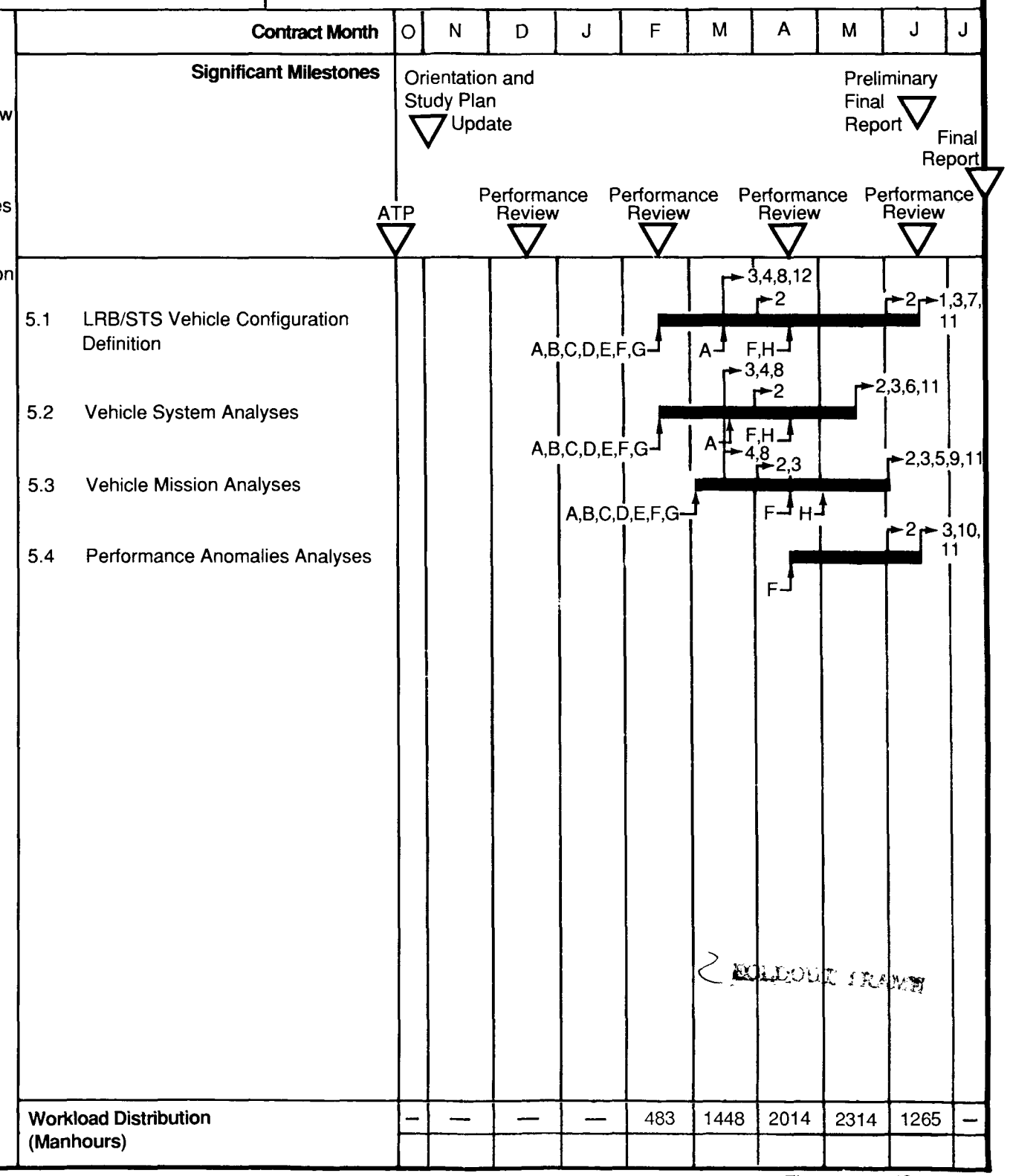

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Figure 1-1 (Continued)

Task Description:

TASK 6.0 (TASK F) SUPPORTING STUDIES AND COORDINATION

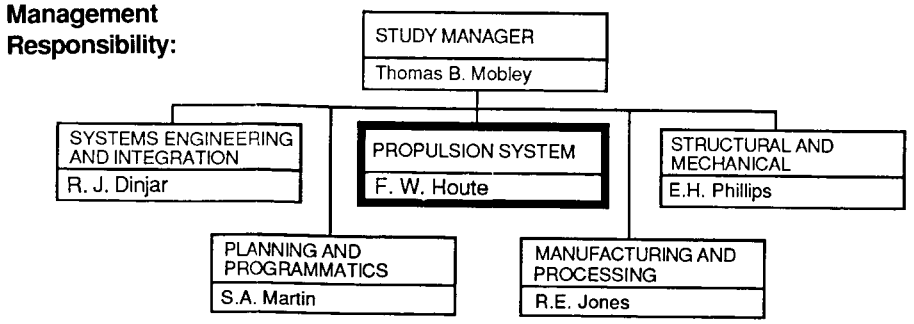
Maintain coordination with current on-going studies, that will provide pump-fed engine data, and two proposed studies, one dealing with LRB integration and the other dealing with adaption of LRBs into STS launch facilities and operations. In addition, obtain data on existing engine systems for possible booster engines.

Task Objective:

TASK 6.0 (TASK F) SUPPORTING STUDIES AND COORDINATION

Obtain existing, current, and new data as it is developed from previous, on-going and future studies on pump-fed and pressure-fed engines and LRBs that will enhance the quality and depth of this study.

Management Responsibility:



Task Approach

TASK 6.0 (TASK F) SUPPORTING STUDIES AND COORDINATION

6.1 Past Studies and Programs - Collect data and evaluate existing designs, such as F-1 and SSME, for potential use as booster engines. Data search of applicable past studies will be conducted and an assessment made for application to this LRB study. These data will be inputted to the other tasks as appropriate.

6.2 STBE and STME Data Review and Monitoring - Monitor on-going studies of Space Transportation Booster Engines (STBE) and Space Transportation Main Engines (STME) and review the data on pump-fed engines of the proposed new design which will be traded in Task A.

6.3 Integration Study Coordination and Support-Monitor and Review - Review the data from the proposed separate study to perform an in-depth analysis or integration of candidate LRB concepts into the STS flight system. The appropriate data will be incorporated into the other study tasks.

6.4 Launch Facilities and Operations Coordination and Support - Monitor and review the data from the proposed separate study to perform a study for adaptation of LRBs into STS Launch Facilities and Operations. The appropriate data will be incorporated into the other study tasks.

FOLDOUT FRAME 1

Task Inputs

A - STBE Study
B - STME Study
C - F-1 Engine Data
D - SSME Data
E - Other Engine Data: Existing Engines & Past Studies
F - Integration of Candidate LRB Concepts into STS Flight System Study
G - Study of Adaptation of LRBs into STS Launch Facilities & Operations
H - Trade & Analyses (Task A)
I - System Definition (Task E)

Task Outputs

1 - Trades and Analyses (Task A)
2 - Pressure-Fed Propulsion System (Task B)
3 - Evolution/Growth Potential (Task C)
4 - System Definition (Task E)
5 - Performance Review Documentation
6 - Final Report
7 - Project Planning (Task G)

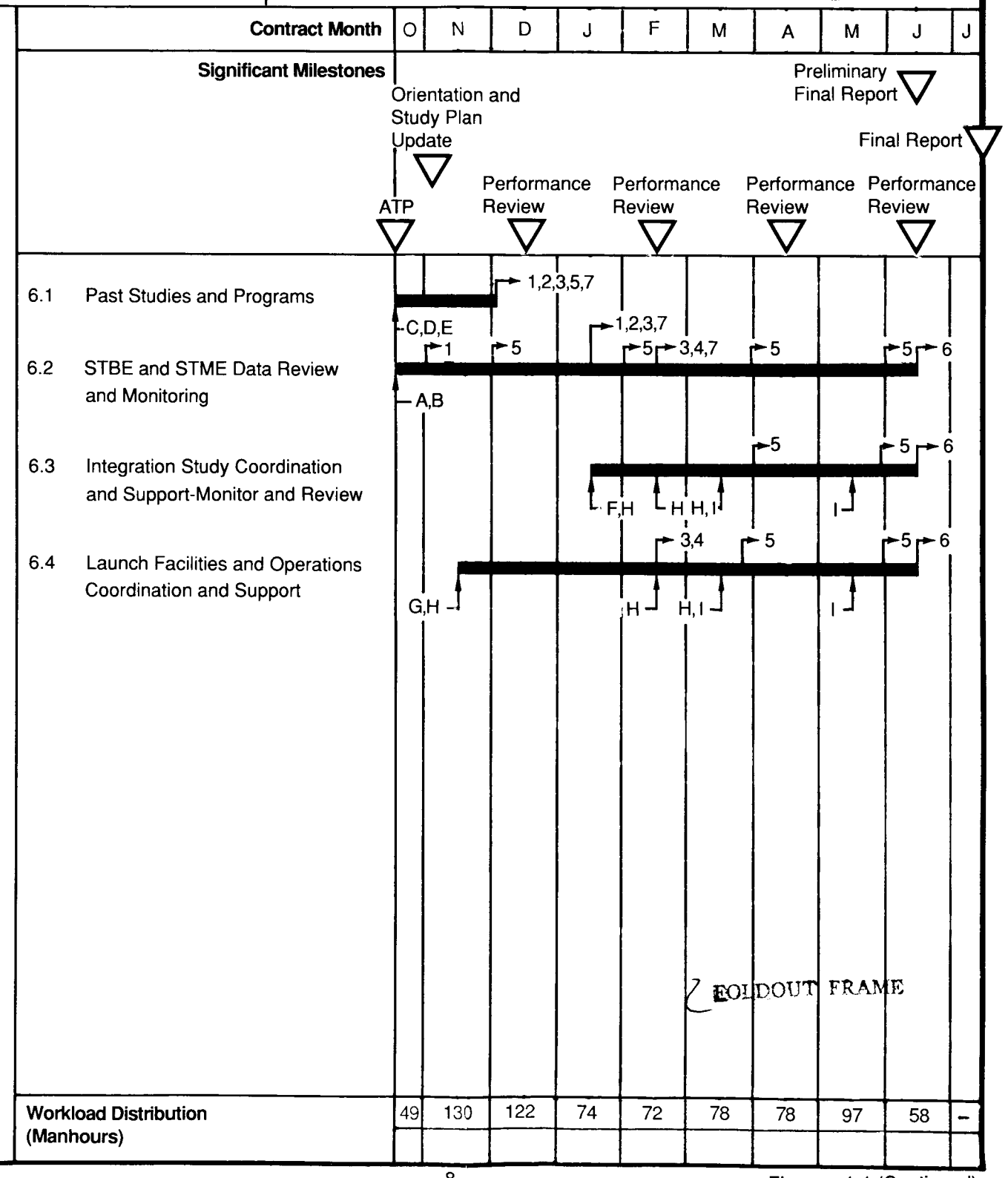


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Figure 1-1 (Continued)

Task Description:

TASK 7.0 (TASK G) PROJECT PLANNING TASKS

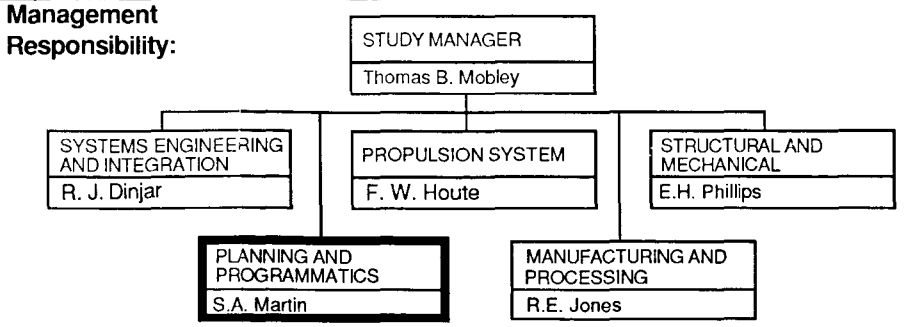
Perform project planning tasks that include 1) the development of a "Preliminary Project Implementation Plan"; 2) development of schedules, including a summary time-phased logic network, project schedule, and supporting schedules; 3) identification of facility requirement with cost and schedule; 4) development of work breakdown structure and dictionary; 5) preparation of project and life cycle cost; 6) identification of technology requirements and the preparation of development plans; 7) performance of an environmental analysis; 8) conduct of a system safety analysis; and 9) development of major systems test requirements and overall test plan.

Task Objective:

TASK 7.0 (TASK G) PROJECT PLANNING TASKS

Provide NASA management level visibility of the LRB Full Scale Development (FSD) phase program which includes requirements implementation approach, cost, and schedule.

Management Responsibility:



Task Approach

TASK 7.0 (TASK G) PROJECT PLANNING TASKS

7.1 Project Planning - Develop a "Preliminary Project Implementation Plan," including planning data for Phase C/D of the recommended LRB concept and supporting equipment, facilities, manpower requirements, etc., in accordance with DR-9.

Program analyses/planning shall be done for each major WBS element and include hardware to the subsystem level, plus software, GSE, GFE, and GFP requirements. The plan shall include procurement, manufacturing, assembly, logistics, logic flow, manufacturing sequence, breadboards, subscale testing, systems testing, system safety, reliability, transportation, etc.

Programmatics analysis of development plans, test requirements, operation plans (ground and flight), and cost estimates are required to the subsystem level. Preliminary schedules for various phases of development and operations shall be included in the plan.

7.2 Schedules - Develop a summary time-phased logic network to the subsystem hardware level. Denote time increments and critical paths for the entire project time period. Develop an overall preliminary project schedule, including primary activities, events, and decision points. Develop supporting schedules detailing the most important functions such as design/development, manufacturing processes, assembly, operations, facilities, etc. The result of this subtask shall be documented in DR-4 "Final Report."

7.3 Facility Requirements - Describe all facilities this project requires (new, old, and/or unique), including major modification to existing facilities. Prepare construction plans, schedules, and costs by fiscal year. The results of this subtask shall be documented in DR-4 "Final Report" and DR-6 "Cost Volume." Include data from the parallel study on Launch Facility Integration by KSC.

7.4 Work Breakdown Structure - Develop a Work Breakdown Structure (WBS) and WBS Dictionary with NASA approval, in accordance with DR-5. The WBS shall be used for structuring the project, plans and schedules, and costs estimates.

FOLDOUT FRAME

Task Inputs

- A - Trades and Analyses (Task A)
- B - Systems Definition (Task E)
- C - NASA WBS Dictionary Comments
- D - Preliminary Analyses of STS Integration (Task D)
- E - New or Existing Technology Requirements from TRRB
- F - Pressure-Fed Propulsion Systems (Task B)
- G - NHB 8800.11 "Implementing the Provisions of The National Environmental Policy Act"
- H - Previous Studies
- I - Evolution/Growth Potential (Task C)
- J - Supporting Studies and Coordination (Task F)

Task Outputs

1 - Preliminary Project Implementation Plan (DR-9)
2 - Logic Network
3 - Project Schedules
4 - Supporting Schedules
5 - Facilities Schedules
6 - Construction Costs
7 - Preliminary WBS (DR-5)
8 - Final WBS (DR-5)
9 - Preliminary WBS Dictionary (DR-5)
10 - Final WBS Dictionary (DR-5)
11 - Performance Review Documentation
12 - Technology Development Plans
13 - Environmental Impact (DR-7)
14 - Preliminary Hazard Analyses
15 - System Safety Criteria
16 - Test Requirements/ Plan
17 - Inputs to Final Report (DR-4)
18 - Trades and Analyses (Task A)
19 - Pressure-Fed Propulsion Systems (Task B)

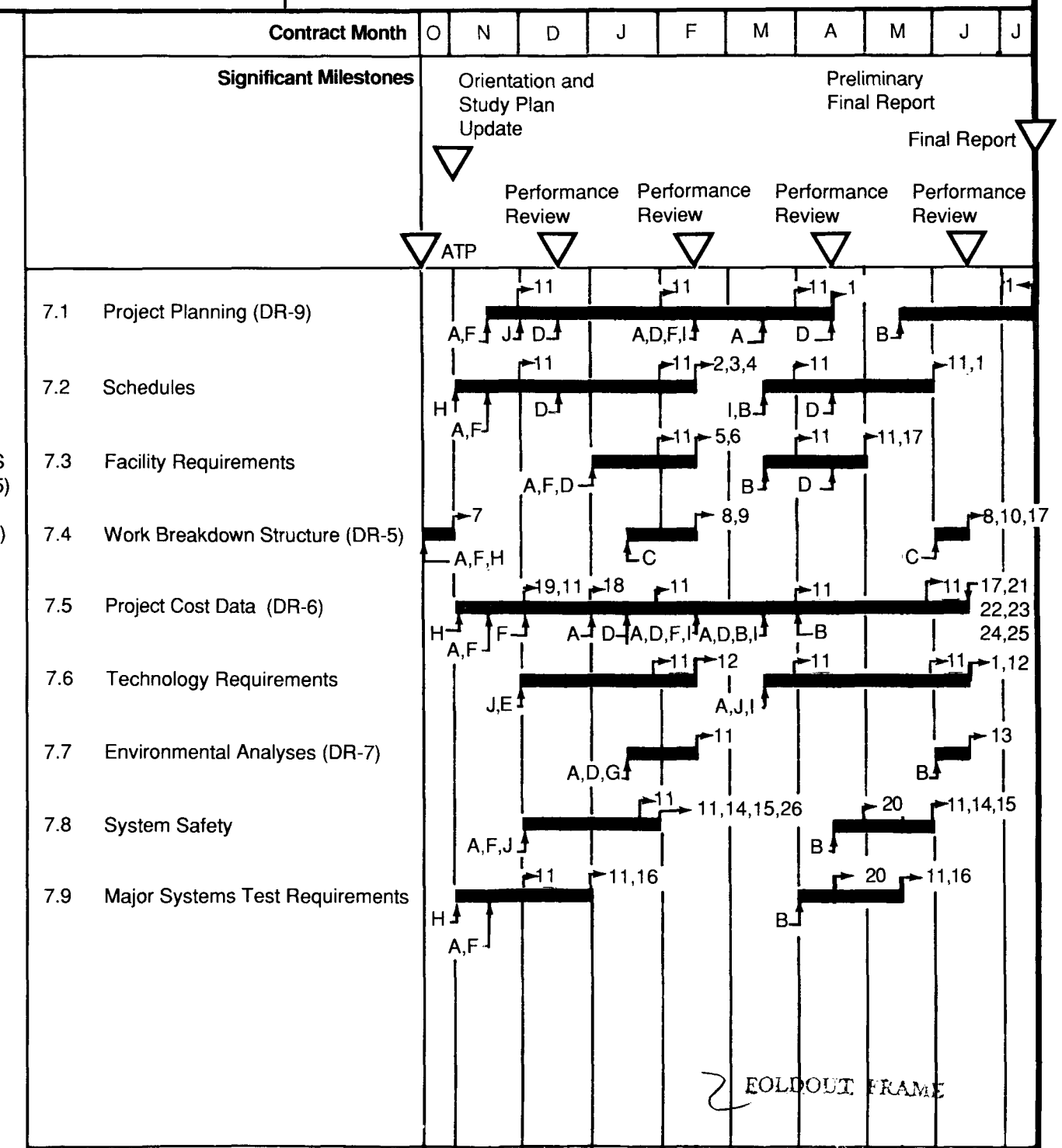


Figure 1-1 (Continued)

Task Description:

Task Objective:

Management Responsibility:

Task Approach (Task G concl)

7.5 Project Cost Data - Project cost estimates in accordance with DR-6 shall be made in FY87 dollars consistent with the depth of technical definition of each WBS element. Separate estimates shall be made for nonrecurring (DDTE), recurring production, and recurring operations costs. Describe the costing methodology; define the basis for the estimates (i.e., vendor quotes, parametric methods, etc.); and define all cost assumptions such as new or existing technology requirements, use off-the-shelf hardware, use of modification of existing designs, etc.

Trade studies preliminary cost estimates shall be made to support the design. Cost comparison analyses shall be conducted as required to establish Life Cycle Costs (LCC), if applicable to the effort.

Estimates of LCC with regard to size and thrust/weight ratio, cost per flight, development of critical technologies, and/or advanced development shall be made. Economic analysis shall be performed to support the rationale for concept selection. The results of these tasks shall be documented in DR-6 "Cost Volume."

7.6 Technology Requirements - Generate a technology development plan for each new or existing technology requirement found during the course of this study. Include task requirements, mode of accomplishment, schedules, objectives, task resources, operations timelines, and anticipated benefits. The results of this task shall be documented in DR-4 "Final Report." New technology needs shall be flagged to NASA's attention as soon as practical after determination of need.

7.7 Environmental Analyses - Perform analysis of potential impacts to the environment this project may create. Satisfy points addressed in the subsequent "Environmental Assessment and Impact Statement" as discussed in NHB 8800.11, "Implementing the Provisions of the National Environmental Policy Act."

Include comparative information on alternatives, brief discussions of the environmental impact of the proposed project and alternatives, and a listing of agencies and persons contacted. The results of this subtask shall be documented in accordance with DR-7 "Environmental Analysis."

7.8 System Safety - Perform 1) Preliminary Hazard Analysis; and develop 2) System Safety Criteria and Requirements; and 3) Technical Risk Management Summary.

7.9 Major System Test Requirements - Provide overall test planning for Phase C/D covering LRB and STS major systems from cradle to grave.

Task Inputs

Task Outputs

20 - System Definition (Task E)
21 - Trade Studies Cost Estimate
22 - LCC of LRB Concepts
23 - DDT&E Costs
24 - Recurring Operations Cost
25 - Program Cost Estimate Document (DR-6)
26 - Preliminary Analysis of STS Integration (Task D)

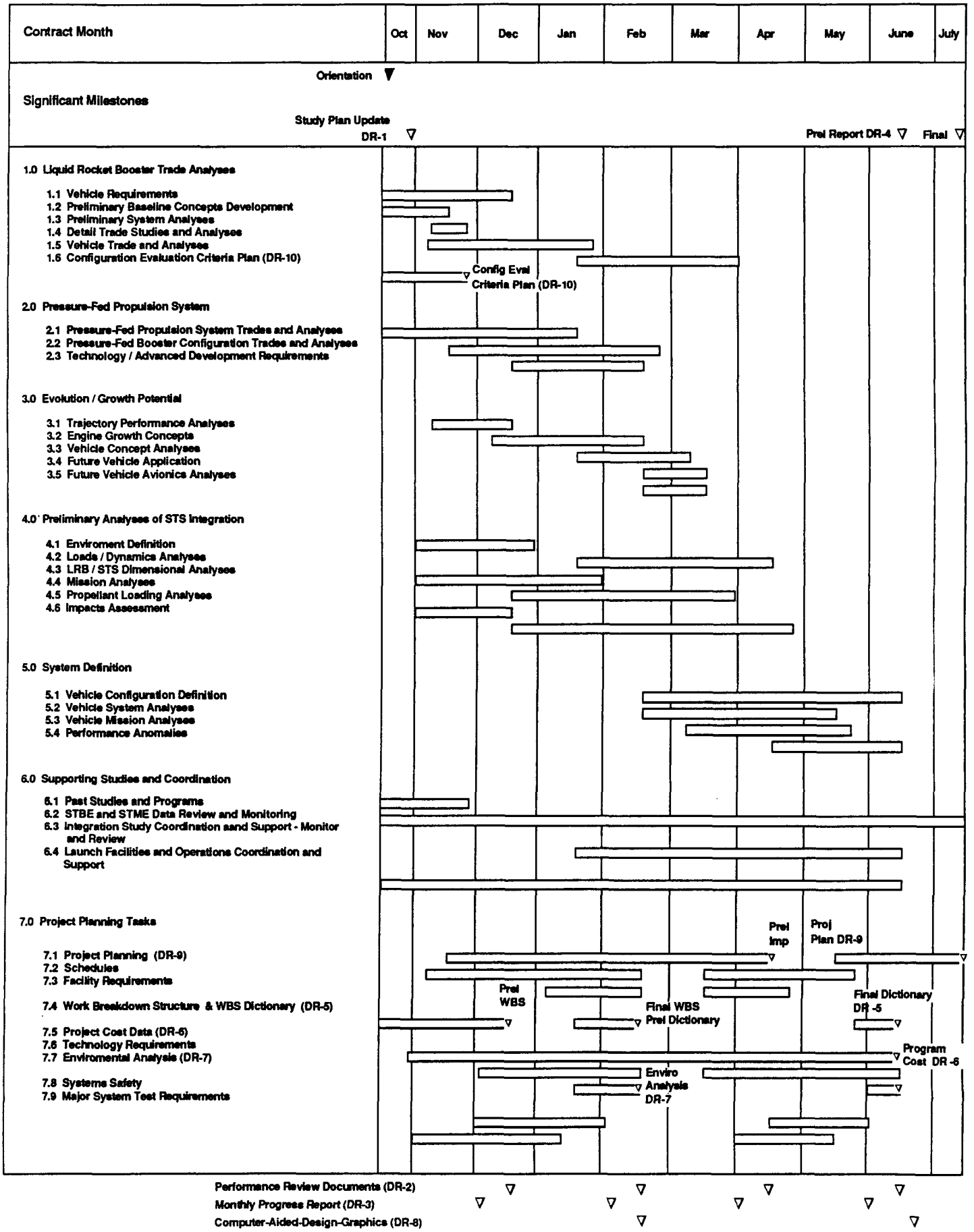
Contract Month	O	N	D	J	F	M	A	M	J	J
Significant Milestones										
Workload Distribution (Manhours)										

Z FOLDOUT FRAME

FOLDOUT FRAME

Figure 1-1

Study Task Summaries



ELEMENT CONTRACT MONTH	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	TOTAL
TASK 1 DENVER SUPPORT	-	275	275	275	-	-	-	-	-	-	825
TASK 1	854	2518	1865	888	787	510	-	-	-	-	7422
TASK 2	80	180	352	364	112	-	-	-	-	-	1088
TASK 3	-	128	361	349	696	476	-	-	-	-	2010
TASK 4	-	688	693	729	574	633	355	-	-	-	3672
TASK 5	-	-	-	-	500	1930	2098	2530	466	-	7524
TASK 6	80	101	64	64	79	78	78	80	78	56	758
TASK 7	240	1003	1199	1635	1595	1463	1995	2029	1278	185	12622
OTS	144	43	43	43	43	43	43	43	43	160	648
AEROJET SUBCONTRACT	-	900	900	1119	1127	1000	1000	-	-	-	6046
HONEYWELL SUBCONTRACT	-	484	364	364	240	360	488	-	-	-	2300
PIONEER SUBCONTRACT	-	-	370	370	240	240	-	-	-	-	1220
CONTRACT MANHOURS	1398	6320	6486	6200	5993	6733	6057	4682	1865	401	46135
OVERHEAD MANHOURS	234	359	296	312	283	312	312	390	312	62	2872
TOTAL STUDY MANHOURS	1632	6679	6782	6512	6276	7045	6369	5072	2177	463	49007

Figure 4-1 Task Level/Time-Phased Manhour Allocations

TASK	SR STAFF ENGR	GROUP ENGR	SR ENGR	PROG ENGR	EST & LCC	PLAN	PROD OPS	PO&E	PROD ASSUR	OTS	TOTAL CONT HOURS	O/H MGMT	TOTAL STUDY HOURS
1.0	558	1115	2498	2230	990	280	576	-	-	-	8247	553	8800
2.0	109	218	326	435	-	-	-	-	-	-	1088	104	1192
3.0	197	394	591	788	-	40	-	-	-	-	2010	283	2293
4.0	367	734	1102	1469	-	-	-	-	-	-	3672	338	4010
5.0	732	1464	2196	2928	-	-	204	-	-	-	7524	516	8040
6.0	75	149	224	298	-	-	-	12	-	-	758	175	933
7.0	46	92	138	184	2606	3814	2194	1248	2300	-	12622	700	13322
DOCUMENTATION	-	-	-	-	-	-	-	-	-	648	648	129	777
SUBCONTRACTS	-	-	-	-	-	-	-	-	-	-	9566	74	9640
TOTAL INDIRECT	-	-	-	-	-	-	-	-	-	-	-	2872	2872
TOTAL	2084	4166	7075	8332	3596	4134	2974	1260	2300	648	46135	2872	49007

Figure 4-2 Task Level Labor Classifications (Includes Denver IDOD)

SUBCONTRACT	TASK DESCRIPTION	MONTHS AFTER ATP 1 2 3 4 5 6 7 8
Aerojet (Subtask Support)	Aerojet will perform five concurrent subtasks that define pressure-fed and pump-fed optimized propulsion system concepts.	
Rev. 2.1	1. Pressure-fed Propulsion System Trades, Analyses, and System Concept - Perform trade studies and analyses to determine an optimum pressure-fed propulsion system concept (i.e., chamber pressure, engine configuration, TVC systems, cost/schedule, etc.).	
1,4, 1.5	2. Pump-fed Propulsion System Concept - Define an optimum pump-fed propulsion concept based on contractor supplied tank study and analyses data and on Aerojet prior in-house studies and programs.	
1.4, 1.5, 1.6, 2.2	3. Booster Vehicle Configuration - Provide support to Martin Marietta in the trade analyses and the conceptual design of booster vehicle using both pump and pressure-fed propulsion systems and in the development of the selection criteria and weighting definition.	
2.2, 2.3, 5.1, 5.2	4. Select Propulsion System Definition - Perform analyses and design efforts to define the selected propulsion system into the booster configuration and future growth concepts.	
7.1 thru 7.9	5. Programmatics - Provide programmatic data on trade studies and selected propulsion systems (i.e., schedules/costs, technology requirements, test requirements, etc.).	
Honeywell (Subtask Support)	Honeywell will perform four concurrent subtasks that define the LRB avionics and flight control systems concepts to be integrated into the booster vehicle configurations.	
1.4, 1.5	1. Preliminary LRB/STS Flight Control /Dynamic Analyses - Support MMMA in detailed and vehicle trade analyses with preliminary flight control definition and dynamic analyses. Assess impacts of MMMA supplied LRB configurations on existing STS flight controls and determine the extent of modifications required and identify any enabling technology.	
3.5, 4.5, 4.8, 4.9, 5.4	2. Flight Controls Integration into LRB/STS Selected Configurations - Perform the preliminary integration tasks to incorporate the modified and/or new elements of the STS flight controls system into the LRB system. Verify the systems with dynamics analyses for both nominal and malfunctioning flights (engine-out). Prepare and outline flight control and avionics concepts suitable for LRB/STS growth and/or future vehicle application.	
5.1	3. Flight Controls/Avionics System Definition - Develop for the selected configuration, avionics systems definition including drawings and supporting analyses.	
7.1 thru 7.6, 7.7, 7.8, 7.9	4. Programmatics - Provide programmatic data on trade studies and selected flight control/avionics system (i.e., schedule/cost, technology requirements, test requirements, etc.).	
Pioneer (Subtask Support)	Pioneer will perform three subtasks that define the LRB system to be integrated into the booster vehicle configurations.	
1.4, 1.5	1. Recovery System Trades - Perform analyses and trade studies to identify recovery concepts to recover all or part of the LRB. Trades will also identify cost/schedule and enabling technologies for each concept.	
5.1	2. Recovery System Definition - Perform design and analyses to define the selected concept from Task 1 which will include component definition, volume, weight installation requirements, etc. Support MMMA with integration of the system into the LRB vehicle design.	
7.1 thru 7.6, 7.7, 7.8, 7.9	3. Programmatics - Provide programmatic data on trade studies and selected recovery system (i.e., schedule/cost, technology requirements, test requirements, etc.).	

Figure 5-1 Subcontractor Study Tasks